UNIT II

RCM PROCESS

Module 4

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Module Preview: **Introduction**

- **Introduction**
- **FMECA**
- **References**
- **Review and Summary**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Module Objective:

Introduction

1. Introduce the concept of Failure Mode, Effects, and Criticality Analysis (FMECA).
2. Define the following FMECA terms:
   - Function
   - Functional Failure
   - Failure Mode
   - Failure Effect
   - Failure Detection
   - Severity Classification
   - Mean Time Between Failure (MTBF)
3. Identify FMECA reference materials

RCM Process

FMECA

PLANNING AND PREPARATION

1. Identify Team and responsibilities
2. Identify analysis items
3. Prioritize Items
4. Identify and document Review Process
5. Orientation/Training
6. Ground Rules and Assumptions

ANALYSIS

1. Equipment Kick-off Meeting
2. Initial Data Gathering
3. Hardware Partition
4. Function
5. Functional Failure
6. Failure Mode
7. Failure Effects
8. Failure Consequences
9. Task Evaluation
10. Task Selection

FMECA

IMPLEMENT RESULTS

1. Package Maintenance Task
2. Implement Other Actions

SUSTAIN

1. Emergent Issues
2. Age Exploration
3. Hardware Changes
4. Trend/degrader analysis
5. Document Reviews

Results

- Analysis Approach/ RCM Plan
- Maintenance Requirements
- Maintenance Program
- Data

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Definition:

FMECA

Process used to determine the functions, functional failures, and failure modes of equipment; and the associated effects, severity, and frequency of each failure modes:

Steps involve identifying…

- **Functions**
- **Functional Failures**
- **Failure Modes**
- **Failure Effects**
- **Severity of Failure effects**
- **Frequency of occurrence**

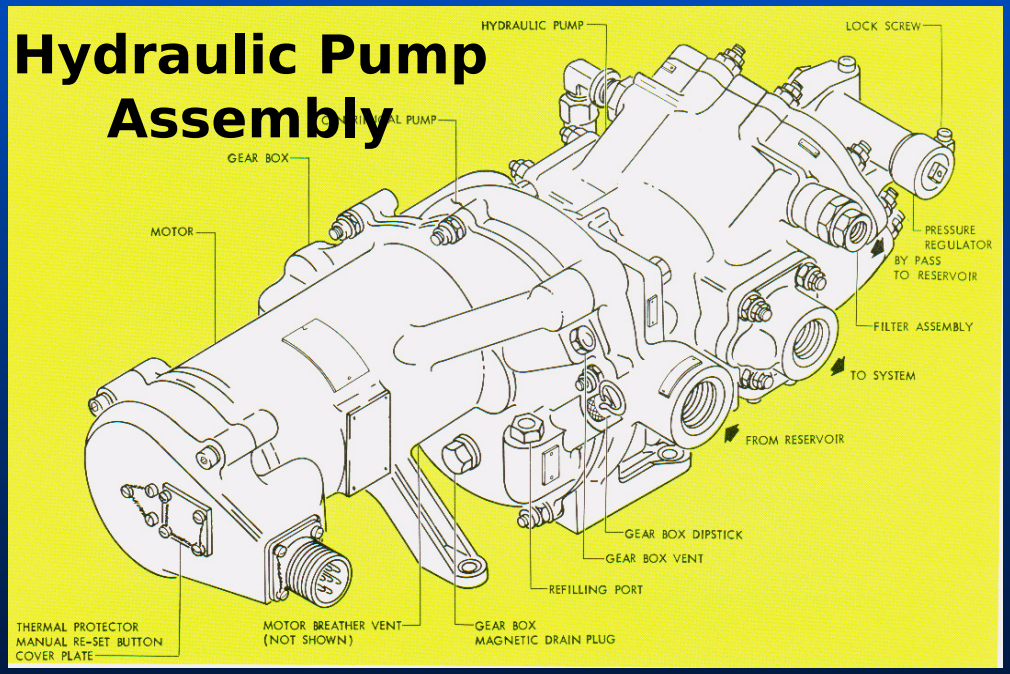
… as they apply to the equipment under analysis in its operating context

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

Hydraulic Pump Assembly



Provides hydraulic fluid at a pressure of 3000 psi +/- 200 psi

FUNCTION

What the user expects the asset or system to do within a required standard of performance.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Functions:

FMECA

- Consider all functions of an item
- Describe functions in terms of specific limits when possible
- State functions in terms of what the item is needed for, not its capability
- Do not combine functions
- Function descriptions should include a verb, object, and applicable limits

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

All equipment has primary and secondary functions

FMECA for RCM analysis should identify ALL primary AND secondary functions. Typical Secondary Functions:

- Control
- Warning or status indication
- Environmental protection
- Physical support or attachment
- Safety or protective functions
- Fluid Containment

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Functions:

FMECA

Function sources:

- **Maintenance Manual description/theory of operation**
- **Operating Manuals**
- **Other tech data providing system descriptions**

Common Errors:

- **Missing secondary functions**
- **Listing functions of lower level hardware items**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Functions:

FMECA

NAVAIR 00-25-403 RCM adds a categorization process to function identification called "significant function identification"

- **Intended to:**
  1) **eliminate analysis of inconsequential functions**
  2) **Ensure all significant functions are identified**

- **Not technically part of the FMECA process**

NAVAIR

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

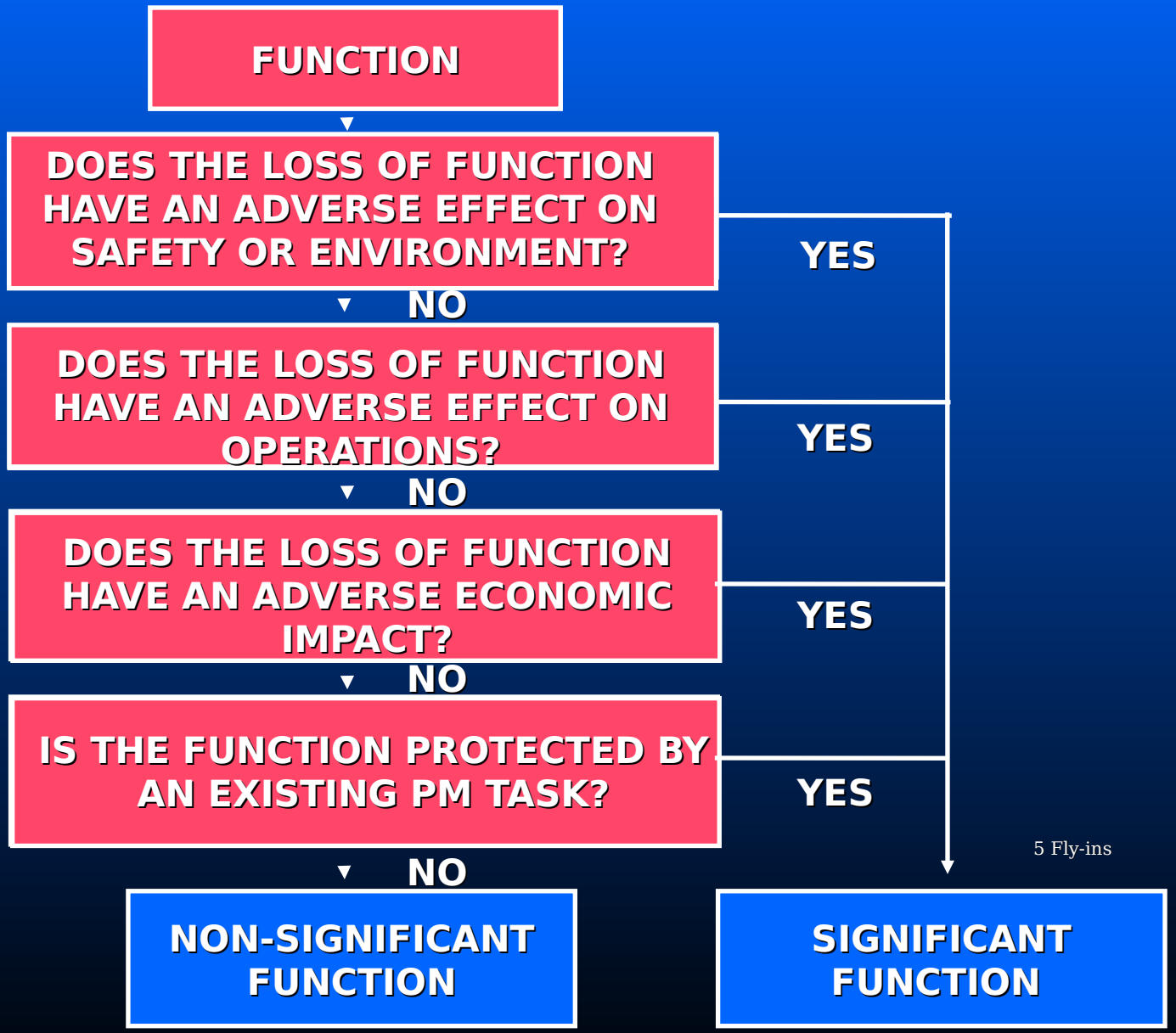
Identifying Functions:

FMECA

A SIGNIFICANT FUNCTION is one whose failure will have adverse effect on the end item with respect to:

- **Safety**
- **Environmental Health**
- **Operations**
- **Economics**

SIGNIFICANT FUNCTION (SF) IDENTFCATION



FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

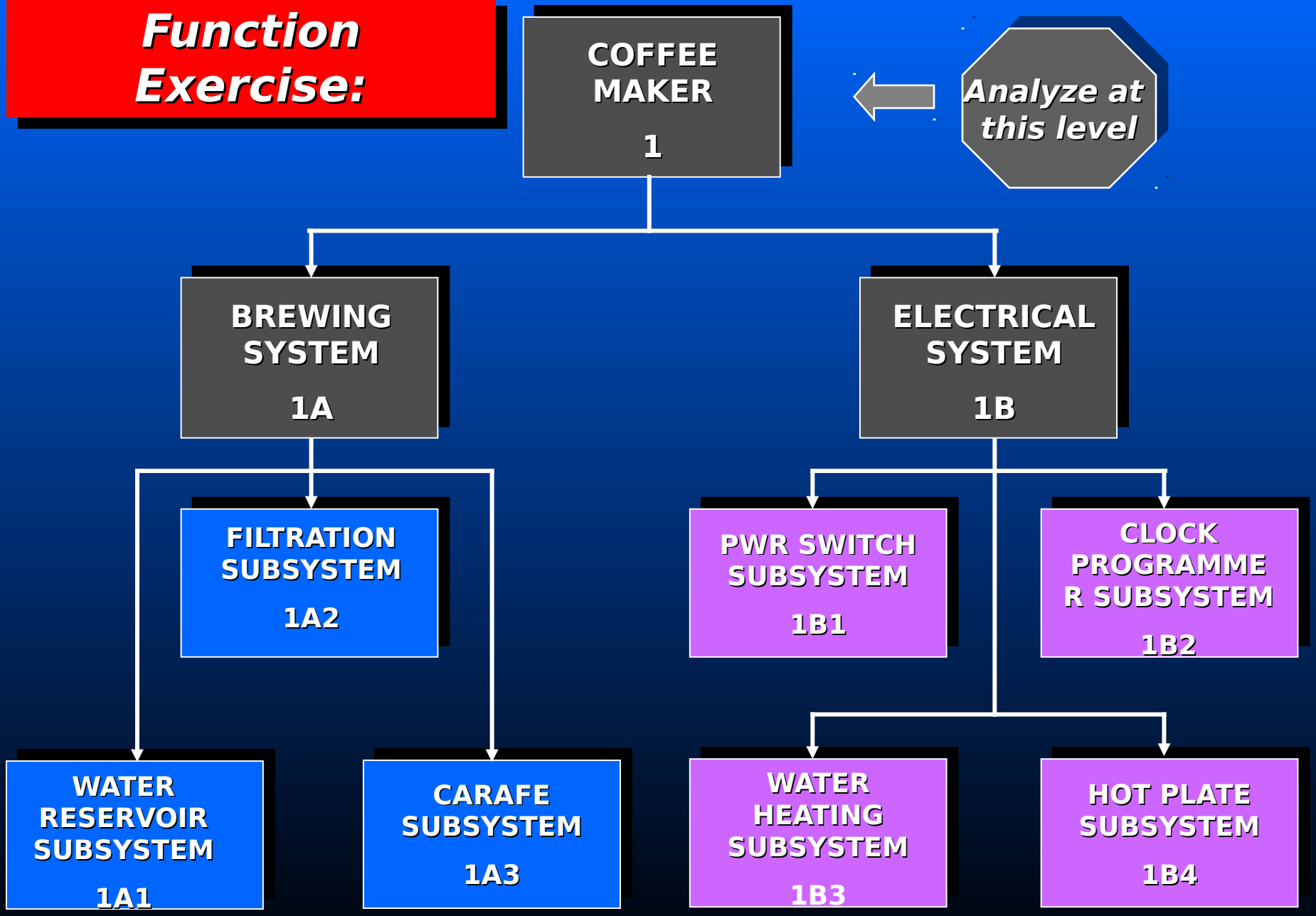
Identifying Functions

FMECA

Class Exercise

Objective:
List the functions of a Coffee Maker

Function Exercise:



Function Exercise:

Remember Secondary Functions:

- Control
- Warning or status indication
- Environmental protection
- Physical support or attachment
- Safety or protective functions
- Fluid Containment
- Comfort and Aesthetics

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

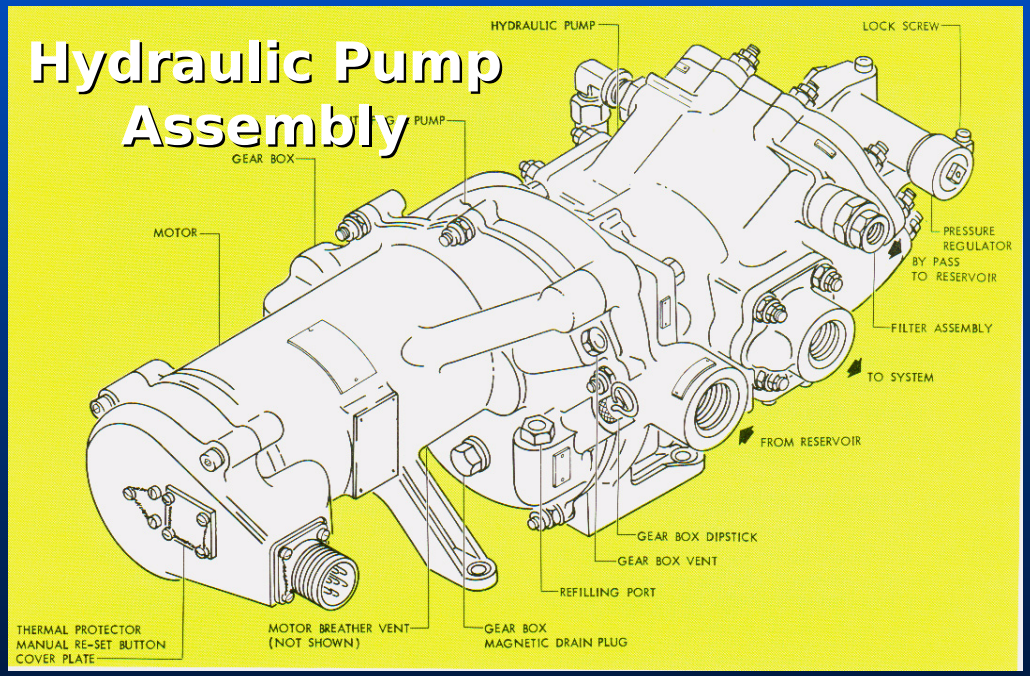
Coffee Maker Functions

1. Brew 1 to 12 cups of coffee
2. Maintain coffee at 120°f ± 5°f
3. Automatically start brewing process within 15 minutes of time specified by user
4. Automatically shut down coffee maker 4 hours after brew cycle is completed
5. Contain coffee in carafe
6. Contain 1 carafe of water in reservoir
7. Provides safe handling of hot coffee

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA



Fails to provide hydraulic fluid at a pressure of 3000 psi +/- 200 psi

FUNCTIONAL FAILURE

The inability of an item to perform a specific function within specified limits.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Functional Failures:

- Note that functional failure may not be a complete loss of the function

- Separate functional failures should be listed where the effects of less than total loss of the function are different from total loss

- Ensure functional failure addresses the function as defined

- Common Errors:
  - Confusion with failure modes of hardware
  - Confusion with potential failures

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

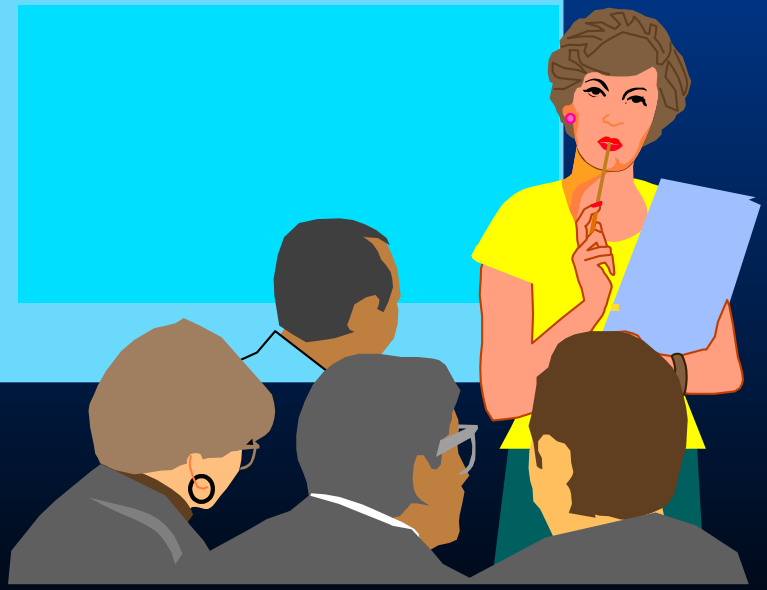
Identifying FMECA Terms: **FMECA**

Class Exercise

Objective:

Identify and list the coffee maker's

Functional Failures



FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Functional Failures

FUNCTION 1 – Brew 1 to 12 cups of coffee

FUNCTIONAL FAILURE A - Fails to brew coffee

FUNCTION 2 - Maintain coffee temperature at 120°f ± 5° f

FUNCTIONAL FAILURE A – Doesn't keep coffee warm(< 100°f)

FUNCTIONAL FAILURE B – Heats Coffee too hot (>125° f)

FUNCTIONAL FAILURE C – Partial warm coffee (>100°f but < than 115°f)

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Functional Failures

FUNCTION 3 - Automatically brew coffee within 15 minutes of time specified by user

FUNCTIONAL FAILURE A - Does not brew coffee at all

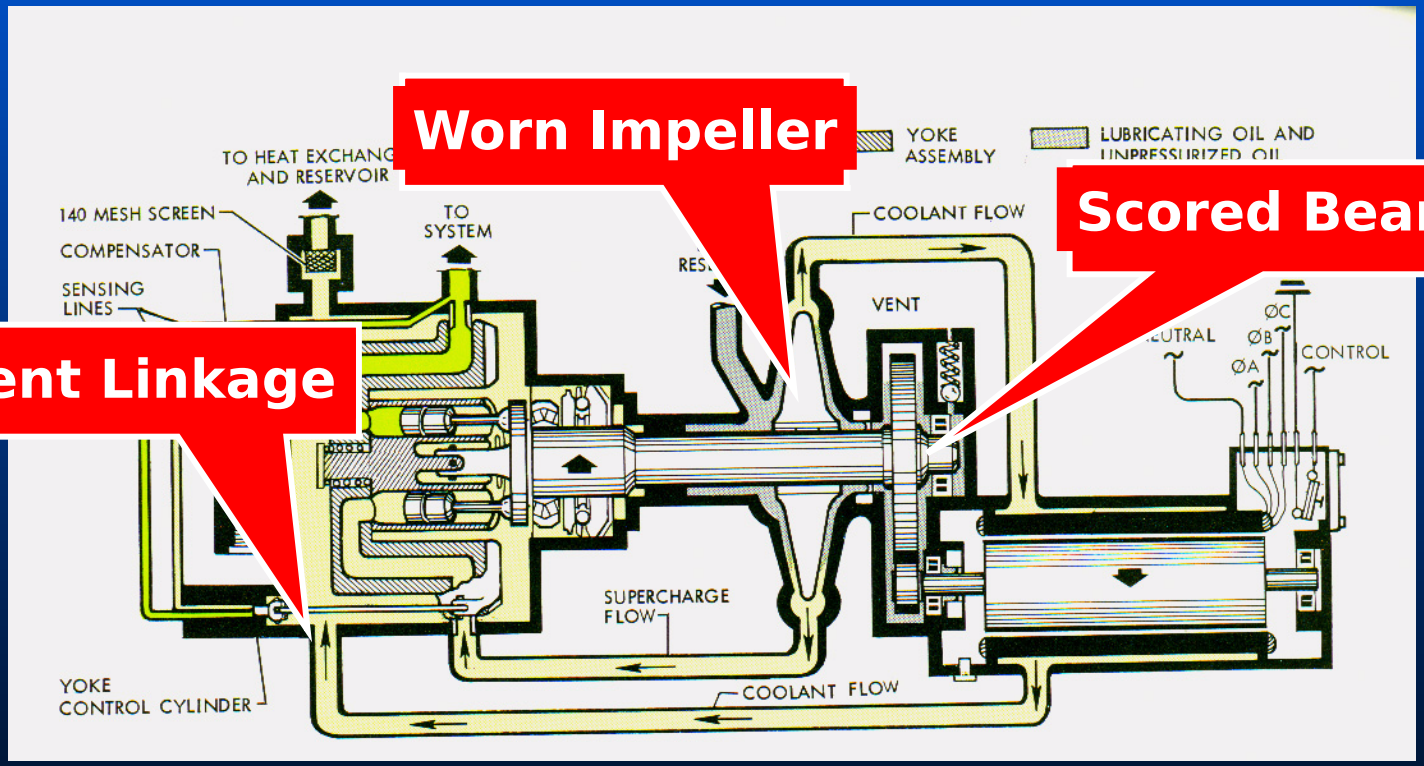
FUNCTIONAL FAILURE B - Brews coffee more than 15 minutes earlier than specified

FUNCTIONAL FAILURE C - Brews coffee more than 15 minutes after time specified by user

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms

FMECA



FAILURE MODE

A specific physical condition that causes a particular functional failure.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Failure Modes:

FMECA

- When possible list failure cause or mechanism, ex. “cracked spar due to fatigue”
- List all failure modes that are “reasonable”.
- Be as descriptive as possible
- Do not combine failure modes where failure effects, rates, or possible failure management solutions may be different
- Methods to identify “significant” failures vary by project.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Failure Modes: **FMECA**

Failure mode sources:

- **Existing PM Tasks**
- **Operating/Maintenance Manuals**
- **Operator/Maintainer Input**
- **Prior FMECA, RCM or other analyses**
- **Failure Databases (Age Exploration)**
- **Engineer/SME input**
- **3M/CMMS data*****

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Failure Modes:

FMECA

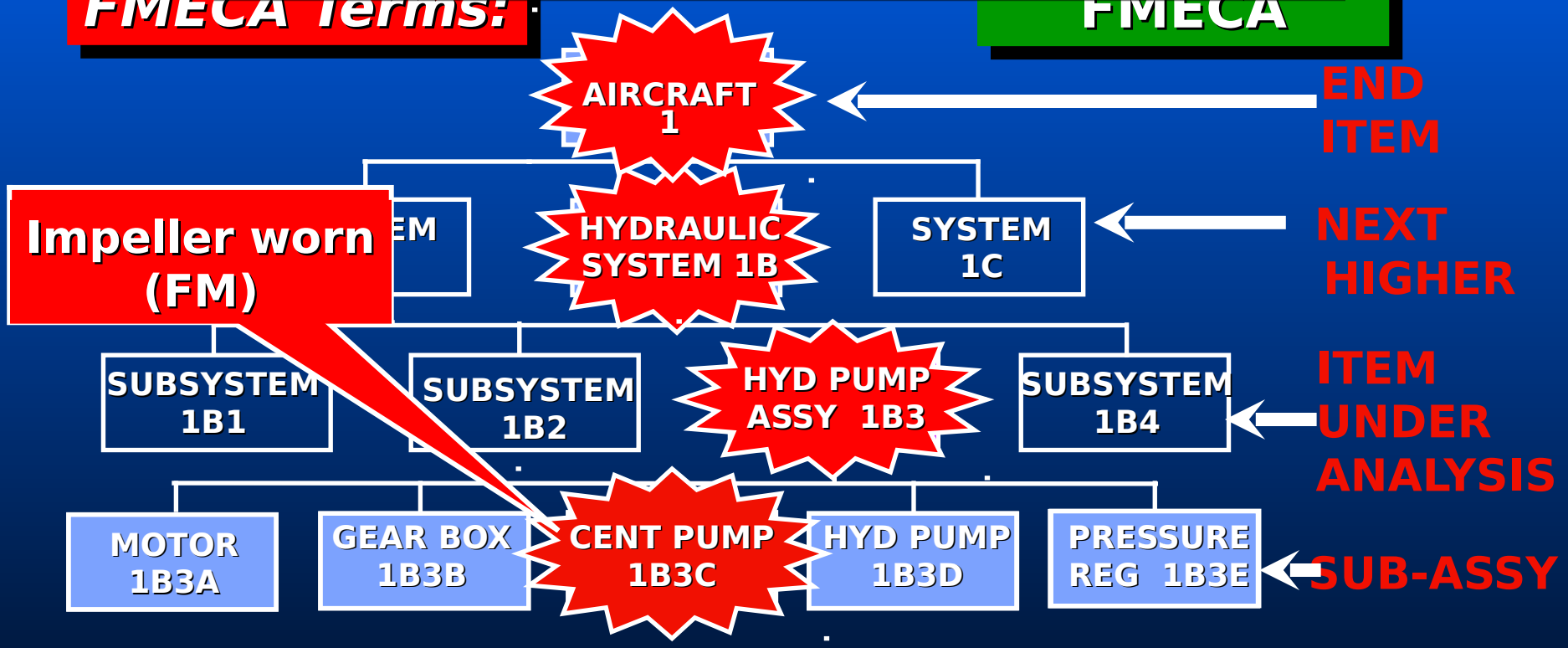
Common Errors:

- **Over dependence on CMMS or other “non-specific” failure data**
- **Lack of specificity in the failure mechanism, (“broken”) or of the failed part/location**
- **Worrying about identifying all failures vice the “important ones”**
- **Confusing potential failures (e.g. “cracks”), induced damage, or secondary damage from failure causes**
- **Failure to apply common sense or analyst/SME knowledge to data**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA



FAILURE EFFECT

The result of a failure mode and it's functional failure on surrounding items, the functional capability of the end item, and hazards to personnel and environment.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Iden

When listing effects:

- **List most severe effects**
- **Should be reasonable**
- **Qualify less likely effects with terms such as “possible” or “potential”**
- **Include restorative actions, as appropriate**
- **Consider compensating provisions**
- **Effects should be identified at point of functional failure**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Iden

When properly identified:

- **Makes the rest of the analysis much easier**
- **Effects must address functional failure but should also consider secondary damage**
- **Hidden failures must assume the condition that makes them evident has occurred**
- **Effects must be clearly related to operational scenarios**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Iden

Pay attention to level of effects:

- **Local: effect on the failed part: “Loss of Impeller effectiveness.”**
- **Next higher: effect on the function of the system/subsystem being analyzed, often synonymous with functional failure: “Loss of Hydraulic Sys #1 pressure.”**
- **End: what the failure means to the asset: “Loss of mission.”**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Sources:

- Operating Manuals
- Maintenance Manuals
- Operator/maintainer/engineer input
- Troubleshooting charts
- SME/Analyst knowledge
- Accident/Incident/Hazard reports
- Failure/Engineering Investigations
- Test reports

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Common errors:

- **Assuming PM in place**
- **Incorrect levels**
- **Ignoring secondary damage**
- **Improper treatment of hidden failures**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying FMECA Terms: **FMECA**

Class Exercise

Objective:

Identify and list the Coffee Maker's

- **Failure Modes**
- **Failure Effects**

Extra Credit

- **Describe how operating context impacts failure effects (Residential vs Commercial Use)**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Failure Modes and Effects

FUNCTION 1- Brew 1 to 12 cups of coffee

FUNCTIONAL FAILURE A – Fails to brew coffee

FAILURE MODE 1 - Clogged heating chamber tubing due to excessive calcium build-up.

FAILURE EFFECT - No coffee

FAILURE MODE 2 - Shorted wiring due to frayed insulation.

FAILURE EFFECT - Possible fire

FAILURE MODE 3 - Open On/Off switch due to corrosion.

FAILURE EFFECT - No coffee

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Failure Modes and Effects

FUNCTION 2 - Maintain coffee temperature at 120°f ± 5°f.

FUNCTIONAL FAILURE A - Fails to heat coffee (< 100°f)

FAILURE MODE 1 – Broken power supply wire to heating element connection.

FAILURE EFFECT - Cold coffee

FAILURE MODE 2 – Heating plate thermostat internal failure.

FAILURE EFFECT - Cold coffee

FUNCTIONAL FAILURE B - Heats coffee to hot (>125° f)

FAILURE MODE 1 – Corroded heating plate thermostat.

FAILURE EFFECT - Possible damage to coffee maker. Possible fire.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Failure Modes and Effects

FUNCTION 2 - Maintain coffee at 120°f ± 5°f. (continued)

FUNCTIONAL FAILURE C - Partially warm coffee (>100°f but < than 115°f)

FAILURE MODE 1 - Corroded heating plate thermostat.

FAILURE EFFECT – Lukewarm coffee

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Failure Modes and Effects

FUNCTION 3 - Automatically brew coffee within 15 minutes of time specified by user

- **FUNCTIONAL FAILURE A** - Does not brew coffee at all
  - **FAILURE MODE 1** - Inoperative Clock due to internal failure
    - **FAILURE EFFECT** - No coffee
- **FUNCTIONAL FAILURE B** - Brews coffee more than 15 minutes earlier than specified
  - **FAILURE MODE 1** - Clock operation too fast due to internal failure
    - **FAILURE EFFECT** - Old, bitter coffee

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Coffee Maker Failure Modes and Effects

FUNCTION 3 - Automatically brew coffee within 15 minutes of time specified by user

FUNCTIONAL FAILURE C - Brews coffee more than 15 minutes after time specified by user

FAILURE MODE 1 - Slow clock operation due to internal failure

FAILURE EFFECT - No coffee until more than 15 minutes after time specified

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Identifying Failure Modes: **FMECA**

A note on “human error” failure modes: RCM may be used to address human error…

Example: “Operator forgot to add water to coffee pot”
Solution: “Post checklist by coffee pot”

However… Care should be taken not to overcompensate for human error where other processes (human factors engineering) or common sense should preside

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

Failure Detection

- Visual alarms
- Audible alarms
- Gauges/Indicators
- Operating characteristics

Identifying Failure Modes

- Voltage checks
- Continuity checks
- Visual inspections
- PHM systems

FAILURE DETECTION

Describes method(s) by which functional failures are detected and failure modes are identified.

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

- Address both operator and maintainer
- For operator: detection of FUNCTIONAL FAILURE (or effects)
- For maintainer: detection of FAILURE MODE

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Sources:

- Operator/maintainer interviews
- Maintenance/Operator's Manuals
- Troubleshooting charts
- Accident/Incident/Hazard reports
- Failure/Engineering Investigations
- Test reports

Common Errors:

- Not addressing both operator and maintainer
- Listing specific PM

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

SEVERITY CLASSIFICATION

A category assigned to a failure mode based on the impacts if its potential effects.

Categories are defined by the organization performing the analysis

Categories for the same failure mode may be different in different operating phases or scenarios

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

SEVERITY CATEGORY

Category I	**Catastrophic**

- **Aircraft example: “Death, Permanent Disability, destruction of equipment/system, damage in excess of $1M, significant breach of environmental regulation.**

- **Critical equipment example: “Death, Permanent Disability, destruction of equipment/system, damage in excess of $1M, significant breach of environmental regulation, Down-time > 2 days**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

SEVERITY CATEGORY

Category I	**Catastrophic**
Category II	**Critical**

- **Aircraft example: “Personal Injury, Damage more than $100K but less than $1M, Inability to perform a critical mission”**

- **Critical equipment example: “Personal Injury, Damage more than $100K but less than $1M, Down-time more than 24 hours but less than two days”**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

SEVERITY CATEGORY

Category I	**Catastrophic**
Category II	**Critical**
Category III	**Marginal**

- **Aircraft example: “Damage more than $1K but less than $100K, Degraded ability to perform a critical mission”**
- **Critical Equipment example: “Damage more than $1K but less than $100K, Down-time more than 8 hours but less than 24 hours”**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

SEVERITY CATEGORY

Category I	Catastrophic
Category II	Critical
Category III	Marginal
Category IV	Minor

- **Aircraft example: “Damage less than $1K, Unscheduled Maintenance or Repair”**
- **Equipment example: “Damage less than $1K, Down-time less than 8 hours”**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Terms:

FMECA

MEAN TIME BETWEEN FAILURE (MTBF)

Basic measure of reliability for an item.

- **Average time between failure occurrences during a specified period with no preventive measures in place**
  - **Usually: Total operating time in given period divided by number of failures that have occurred**
  - **Inverse of the failure rate**
  - **Adjustment required if PM is already in-place**

Used in RCM for prioritizing failure modes, performing cost analysis and Failure Finding Task Interval Calculations

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

CALCULATING MTBF (Method 1)

- Total operating time/number of failures (mature populations in a specified time period)
- When no failures have occurred use a conservative estimate
  - Evaluate like and similar equipment
  - Consider possibility of failure in short period of time

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Calculating MTBF:

FMECA

Sources:

- **CMMS data**
- **Third party repair records**
- **Supply usage data**
- **Artisan/Maintainer anecdotal estimates**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Method 1 Cautions:

- **Need data specific to item**
- **Understand difference between potential failures and functional failures**

  Note: MTBF based on potential failures may need adjustment
- **Adjustments may be required to establish MTBF where PM is already in place**
- **Make sure time period chosen is representative (steady-state)**
- **Assumes constant failure rate of the population**
- **May require periodic monitoring/update**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

CALCULATING MTBF (Method 2)

Use Design or predicted values

- Data sources:
  - Design/vendor specs
  - "Like and similar" equipment
  - Analytical/handbook predictions
- Caution: Often inaccurate
  - Verify with real data if possible
  - Adjust with conservatism where necessary
  - Monitor/Update when field data becomes available

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

CALCULATING MTBF (Method 3)

Statistical Modeling methods

- **Beyond scope of this course**
  - **Requires specialized training and knowledge**
- **May be most accurate if properly performed**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Criticality

- Combination of Severity and Frequency (MTBF)
  - Hazard Risk Index (HRI)
  - Risk Priority Number (RPN)

SEVERITY \ FREQUENCY	FREQUENT (A) ≥ 1 per 1,000 Hours	PROBABLE (B) ≥ 1 per 10,000 Hours	OCCASIONAL (C) ≥ 1 per 100,000 Hours	REMOTE (D) ≥ 1 per 1,000,000 Hours	IMPROBABLE (E) < 1 per 1,000,000 Hours
CATASTROPHIC (I) • Death or Permanent disability • Significant Environmental breach • Damage > $1M, Downtime>2 days • Destruction of system/equipment	1 HIGH	2 HIGH	4 HIGH	8 MED	12 ACCEPT
CRITICAL (II) • Personal Injury • Damage >$100K and < $1M • Loss of availability > 24 hrs and < 7 days	3 HIGH	5 HIGH	6 MED	10 LOW	15 ACCEPT
MARGINAL (III) • Damage >$10K and < $100K • Loss of availability > 4 hrs and < 24 hrs	7 MED	9 MED	11 LOW	14 ACCEPT	17 ACCEPT
MINOR (IV) • Damage <$10K • Loss of availability < 4 hrs	13 ACCEPT	16 ACCEPT	18 ACCEPT	19 ACCEPT	20 ACCEPT

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

FMECA Summary:

FMECA

- **Item – What it is**
- **Functions – What you want item to do**
- **Functional Failures – How it fails to do it**
- **Failure Modes – Why it fails to do it**
- **Failure Effects – What happens**
- **Severity of Failure – How bad it is**
- **Failure Frequency – How often it happens**
- **Criticality – Severity + Frequency**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Guidance: References

- NAVAIR 00-25-403: Guidelines for the Naval Aviation RCM process
- SAE JA1012: Society of Automotive Engineers Guide to RCM Standard
- RAC-HDBK-1120: FMECA - Failure Mode, Effects and Criticality Analysis
- MIL-STD-1629A: Procedures for Performing a Failure Mode, Effects, and Criticality Analysis
- MIL-HDBK-217: Reliability Prediction of Electronic Equipment.
- MIL-STD-882D: Standard Practice For System Safety
- NAVAIRINST 5100.11: Research and Engineering Review of Risk Process and Procedures for Processing Grounding Bulletins

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Sources:

References

Useful Data Sources For Identifying FMECA Information are:

- **Maintenance/Operators Manuals**
- **Troubleshooting Guides/Charts**
- **Drawings**
- **Operators/Maintainers/Engineers/OEM Tech Reps**
- **Work Orders/CMMS or other failure data**
- **Block Diagrams/Schematics**
- **Existing PM Tasks**
- **Accident/Incident/Hazard reports**
- **Engineering/Failure Investigations/Test reports**

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Review and summary

Module Objective

Provided an understanding of the Failure Modes, Effects, and Criticality Analysis

Introduction

Learning Objectives

FMECA

- Definition of a FMEA
- Purpose of a FMECA
- Definitions & Identification Process

References

End of Module

up next.....

RCM Decision Logic